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University uses on-campus abandoned well to simulate deepwater well-control operations

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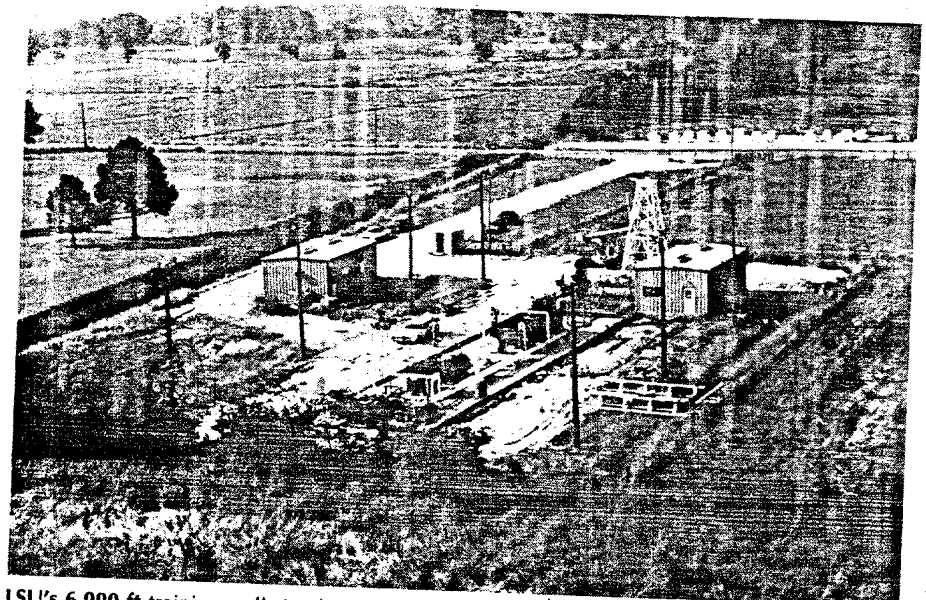
A new $2-million facility for well control research and training was recently dedicated at Louisiana State University.

The facility is centered around a 6,000-ft well complete with subsurface equipment which allows essentially full scale modeling of the flow geometry present on a floating drilling vessel operating in 3,000 ft of water. Extensive new surface equipment also was installed to allow highly instrumented well-control experiments and training exercises to be conducted.

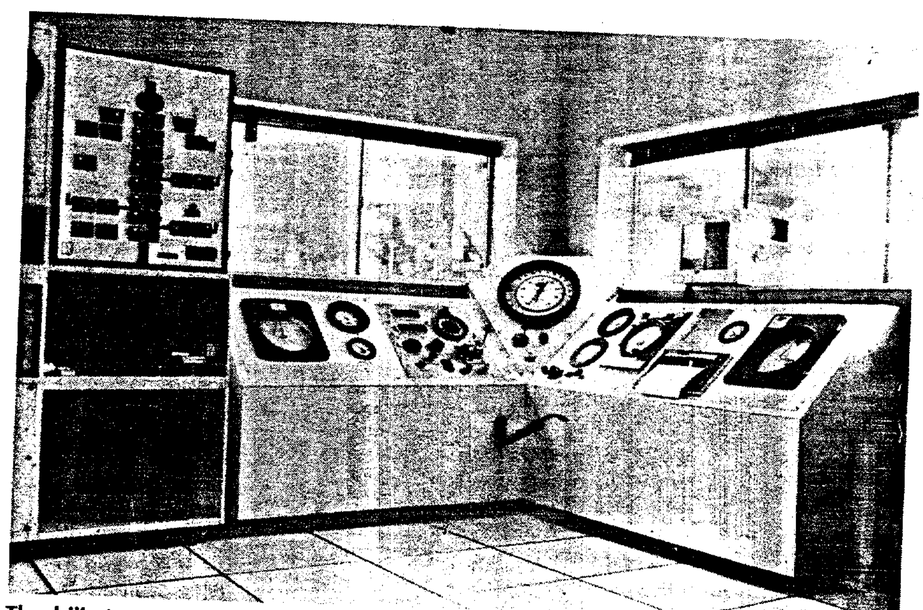
The new facility is a major expansion of the LSU Blowout Prevention Research & Training Center.

Funding for the new research and training well facility was obtained through the combined support of a consortium of 53 companies in the petroleum and construction industry (Table 1). The project was given a big boost when Goldking Production Co., after drilling a 10,000-ft, $670,000 dry hole on the LSU campus agreed to donate the well to LSU.

Thirteen major oil companies contributed special grants totaling $200,000 for the needed well completion work and surface facilities. Grants of equipment and services valued at approximately $1,200,000 were provided by 40 service companies in the petroleum and construction industries. In addition, approximately $200,000 of the well completion and site preparation costs were provided as part of a research contract sponsored by the U.S. Minerals Management Service (formerly the U.S. Geological Survey).



LSU's 6,000-ft training well simulates a deepwater well with subsea BOPs. Some surprising results have come from experimentation with the first facility able to model subsea well control (Fig. 1).



The driller's control panel offers a realistic touch, similar to an actual floating drilling vessel (Fig. 2).

Test well. The recently completed well facility is shown in Fig. 1. The main features of the facility include:

- A 6,000-ft well
- A choke manifold containing four 15,000-psi adjustable drilling chokes of varying design features
- A 250-hp triplex pump
- Two mud tanks with a combined capacity of 550 bbl
- A high capacity mud-gas separator
- Three mud degassers of varying design
- A mud-mixing system
- An instrumentation and control house

Figs. 2 and 3 show some of the instrumentation in the control house.

Special capabilities. The subsurface configuration of tubulars in the well was chosen so the well would exhibit the same hydraulic behavior during pressure control operations as a well being drilled from a floating drilling vessel in 3,000 ft of water.

The blowout prevention problem on a floating drilling vessel is complicated by the location of the blowout preventer (BOP) stack at the seafloor rather than at the surface and the use of multiple high pressure subsea flowlines from the BOP to the surface.

In shallow water, this system behaves much like well control equipment on a land rig or on a bottom supported marine rig. However, when modeling very deep-water wells further offshore, the consequences of this special flow geometry become much more pronounced. As shown in Fig. 4, the number of wells drilled in water depths exceeding 2,000 ft has increased significantly in the past few years.

The effect of locating the BOP at the seafloor is modeled in the training well using a Baker packer and a Baker triple parallel flow tube as shown in Fig. 5. Subsea flow lines connecting the simulated BOP to the surface are modeled using 2.375-in. tubing. A subsea wing valve on one flow line is modeled using a Hydril surface-controlled subsurface safety valve.

This allows experiments and training exercises to be conducted using only one flow line with the other isolated from the system, as is often the case in well-control operations on floating drilling vessels.

Drill pipe is simulated using 6,000 ft of 2.875-in. tubing. Nitrogen gas is injected into the bottom of the well at 6,000 ft to simulate influx from a high pressure gas formation. The nitrogen is injected into the well through 6,100 ft of 1.315-in. tubing, which was placed inside the 2.875-in. tubing.

Nitrogen is used instead of natural gas to eliminate any potential fire hazard.

A Sperry Sun pressure transmission system was placed at the bottom of the nitrogen injection line to allow continuous surface monitoring of the bottom hole pressure during simulated well control operations. The pressure signal is transmitted through 0.125-in. OD capillary tubing which is strapped to the 1.135-in tubing. A check valve located at the bottom of the nitrogen injection line allows this line to be isolated from the system after the gas kick is placed in the well.

Research program. A four-year experimental research program on the development of improved blowout prevention procedures for deep-water drilling operations is being funded by an $823,000 research contract with the U.S. Minerals Management Service. Principal investigators for the project include Dr. A.T. Bourgoyne, professor of petroleum engineering and department chairman, Dr. William R. Holden, professor of petroleum engineering, and Dr. J.P. Langlinais, assistant professor of petroleum

Table 1

Contributors to LSU test well

Special grants

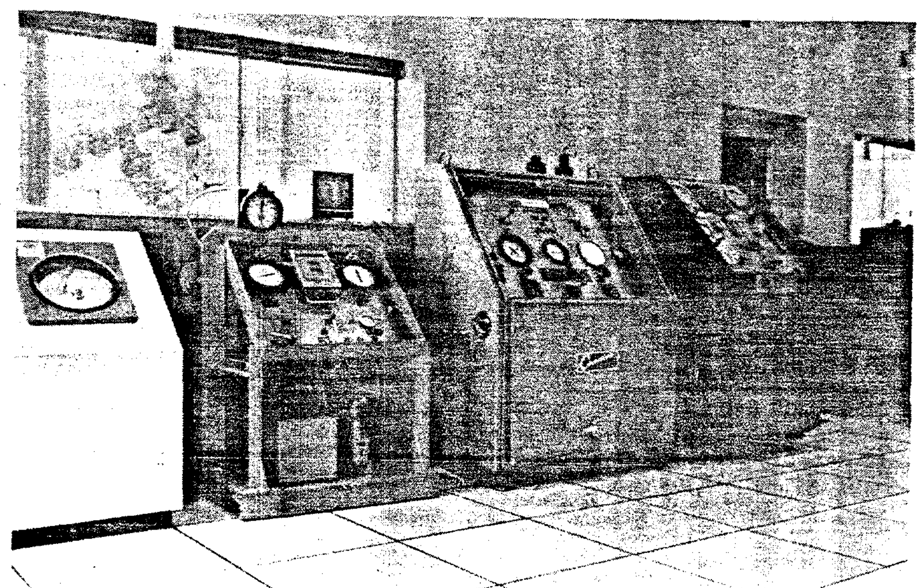
Amoco Production Co.
ARCO Oil & Gas
Chevron Oil Co.
Conoco Inc.
Exxon Co. USA
Getty Oil Co.
Gulf Oil Co.
Marathon Oil Co.
Mobil Oil Co.
Phillips Petroleum Co.
Shell Oil Co.
Tenneco Oil Co.
Texaco Inc.

Equipment and services grants

B & R Drilling and Workover Services
Baker Packers and Completion Systems
Baker Service Tools
Bakerline-Torque Turn
Burgess & Associates
Cameron Iron Works
Champion Pneumatic Machinery Co.
Chromoloy-Delta Mud
Daniel Industries Inc.
Dixie Oil Tools
Flournoy Drilling Co.
Gator Hawk
Gearhart
General Equipment
Goldking Production Co.
Gray Tool Co.
Halliburton
HOMCO
Hydril Co.
Hughes Tool Co.
Ideal Machine Co.
K & W Fishing Tools
Koomey Inc.
Martin Decker Corp.
Milchem Inc.
National Supply Co.
NOWSCO Well Services
NL Baroid
NL Treating Chemicals
NL Rig Equipment
Otis Engineering Co.
Quintana Petroleum
Red Fox Machinery
Sperry Sun
Sun Oil Co.
Dresser Industries-SWACO Division
TOTCO
Union of Texas Gas Co.
Wilson Steel Co.
Westinghouse
WKM-Valve Division

Research contract

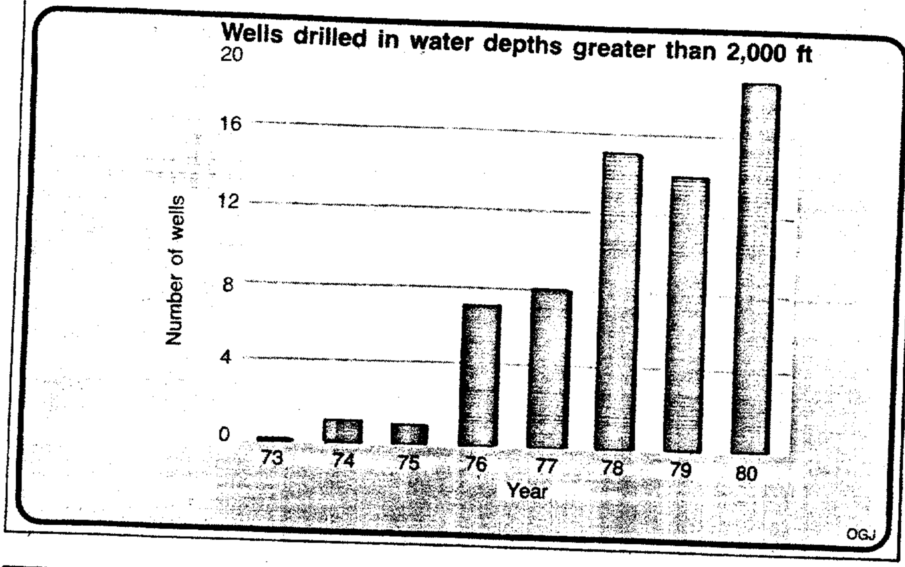
U.S. Minerals Management Service



Choke controls here are operated for both research and training. Initial experience has shown that a human driller is far from infallible (Fig. 3).

Deepwater wells

Fig. 4



engineering. James H. Sykora, coordinator of the new facility, is another key person in the experimental research program, and several MS and PhD candidates are also involved.

Special problems being addressed in the experimental research program include: procedures for safe handling of upward gas migration in a shut-in well, improved procedures for initiating circulation of the formation fluids from the well, and improved procedures for handling the rapid loss of hydrostatic pressure which occurs when the gaseous formation fluids reach the subsea flow lines.

Many different alternative procedures that have been published are being evaluated. Also, basic research on two-phase annular flow patterns is being conducted to improve the understanding of the subsurface pressure changes which occur during the pres-

Well design selected to model deepwater well-control operations

Fig. 5

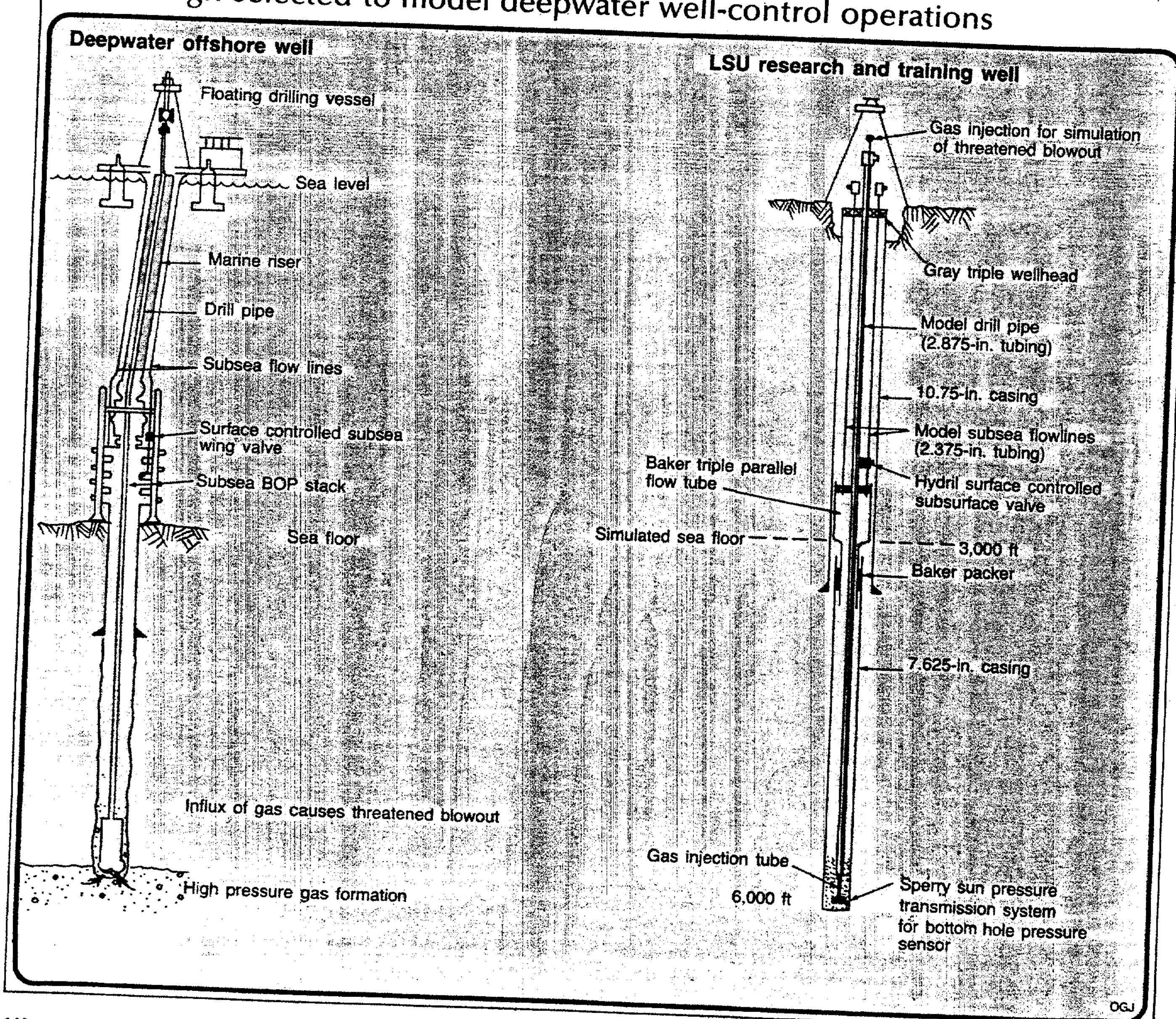


Table 2

Advanced well-control schools

Deep-water floating drilling operations

Course outline

Day 1

1. Special problems associated with well control operations in deep water (1 hr)
2. Equipment familiarization (1 hr)
   a. Description
   b. Hands-on familiarization
3. Measurement of circulating pressures and chokeline friction (½ hr)
   a. Theory
   b. Practical exercise using well
4. Pump start-up procedures (1 hr) with minimum risk of hydrofracture
   a. Theory
   b. Practical exercise using well
5. Techniques for handling gas zone elongation when kick reaches sea floor (½ hr)
6. Practice calculations and electronic simulator exercises (3 hr)
7. Techniques for handling upward migration in a shut-in well with subsea stack (1 hr)

Day 2

8. Practical exercises using actual gas kicks. After each exercise, a critique is given.

   A. Small gas kicks (2 hr) (kick volume less than choke line volume)

   B. Moderate gas kicks (2 hr) (kick volume approximately equal to choke line volume)

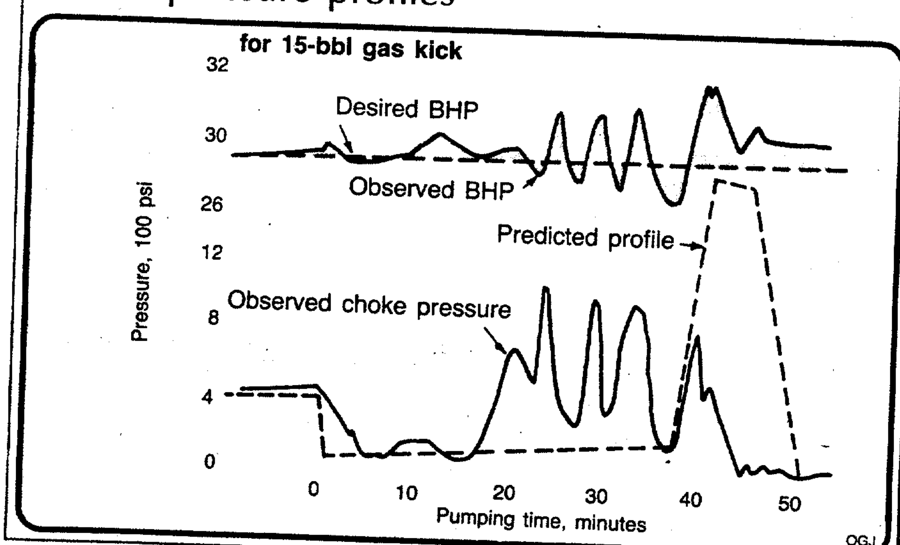
   C. Large gas kick using single choke line (2 hr) (kick volume much larger than choke line volume)

   D. Large gas kick using two choke lines (2 hr)

   E. Optional upward gas migration exercise (3 hr)

Choke pressure profiles

Fig. 6



sure control operations. An ultimate goal of the research program is the development of more accurate algorithms for use in computer simulations of well-control operations. It already has been shown that present-day computer simulators do not always realistically model actual well behavior when gas is present.

Shown in Fig. 6 are the results of a typical well-control exercise conducted using the new well facility. Also shown for comparison are theoretical results predicted for an "infallible choke operator" using a computer simulator.

Note that the observed pressure peak occuring when gas displaces mud from the subsea flowline occurred sooner than computed due to upward gas migration through the mud. The magnitude of the pressure peak was significantly less than that computed because of the existence of a complex two-phase flow pattern in the choke line rather than a complete displacement of mud by gas. Note also the difficulty experienced by the choke operator in maintaining a constant bottom-hole pressure after the gas kick reached the subsea flowlines.

It has been found that many individuals require considerable practice to achieve a relatively constant bottom-hole pressure for the unique well geometry present in deep-water drilling operations.

Training program. The LSU department of petroleum engineering, working in conjunction with the division of continuing education, has played an active role over the past 10 years in the training of industry personnel in present-day methods of blowout prevention. The original LSU training well equipped to model land-based pressure control operations was constructed in 1971 with the help of the International Association of Drilling Contractors (IADC) and many of the major oil companies and service companies. This well is still in operation.

The U.S. Minerals Management Service in its "OCS Training Standard T-1" sets forth requirements for well-control training for drilling personnel who work offshore under federal jurisdiction. Since 1978, the LSU Blowout Prevention Training Program has offered MMS-approved comprehensive and refresher pressure-control courses leading to certification on both surface and subsea BOP stacks.

In addition, a new two-day advanced pressure control school for deep-water floating drilling operations is being introduced. The advanced school is taught at the new research and training well facility and emphasizes hands-on training. Class size is limited to eight participants to allow each student to obtain practical experience in several pressure control situations. An outline of the new advanced school utilizing the new well facility is given in Table 2.

Many individuals have requested special advanced schools run in conjuction with a certified refresher course for subsea stacks. In response to these requests, a one-day advanced course is offered immediately following a one-day certified refresher courses for subsea stacks. The one-day advanced course contains essentially the same practical exercises shown in Table 2 for the second day of the two-day advanced course.

The new well facility is also available to the industry for special experiments or in-house schools. ■

The author...

Bourgoyne

A.T. Bourgoyne Jr. is chairman of the petroleum engineering department at LSU. Prior to joining LSU in 1970, he worked in the production engineering services group of Continental Oil Co. in Houston. He holds BS and MS degrees in petroleum engineering from LSU and received his PhD in petroleum engineering at the University of Texas at Austin. He is currently writing a textbook on drilling and is chairman of the SPE manpower committee.